International Standardization of Lithium-Ion Battery for Space craft

Takeshi Kiyokawa (SJAC/MELCO)

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SJAC: The Society of Japan Aerospace Companies
MELCO: Mitsubishi Electric Corporation

1.Purpose of International standardization

•Recently, Lithium-ion batteries (LIBs) are used more frequently in the commercial missions of space industry.

•Especially, it is notable to see the application of the commercial-off-the-shelf (COTS) based batteries.

•It is forecasted that new LIBs for space application will be developed based on the consumer products including electrical vehicles one after another within a couple of decades.

•This is a unique trend to LIB and not seen in current Nickel Cadmium and Nickel Hydrogen batteries for space application.

1.Purpose of International standardization (continued）

•Since COTS products changes faster than spacecraft lifecycle, new LIBs will be developed for COTS products. For space industry, a challenge is to use newly developed LIB maturely.
It is also important to ensure the long-term quality stability once new LIB developed.

•Of course, any spacecraft must comply with the range safety requirements of space agencies when launched by their launch sites.

•An appropriate standard for LIB application is needed. And the standard should be shared in the world space industry to assure the mission quality and safety.

1.Purpose of International standardization (continued）

Consideration in the international standard development

•It is needed to consider the LIB technical trend to ensure long-term quality stability and safety.

•It is important to manage the COTS based technology so that it will be built into spacecraft quality (harmonization of space quality standards and the consumer product standards).

1.Purpose of International standardization (Benefits）

- ***International standard of LIB for Spacecraft***
  - ✓***can provide the single common baseline in the world.***
  - ✓***can merge similar tests and evaluations for battery development efficiency.***

↓

✓***International work-sharing could increase in the development of the LIB, based on the standard.***

✓***Since the standard development and engineering test items are publicized,***
entry of new manufactures in LIB development will increase.

✓***Compatibility in the LIBs will mitigate the risk of development of satellite program.***

✓***Clarifications of LIB performance enable spacecraft engineers to optimize the LIB systems for specific missions.***

↓ More..

By specifying what the LIB for spacecraft is, the performance, quality and safety of LIB will be sustained!

2. Scope

For the purpose of activate the space industry, considering any items "from electrolyte filling to the end of the mission in space"

High performance, safety, and high efficiency of distribution

Scope of this standards activity

Usage for Spacecraft

1. **Spacecraft means the satellites (LEO, GEO, and TFO and including space science mission) and launch vehicles.**
2. **Battery assembly.**
3. **Useful standard for battery developer and spacecraft system architectures.**
4. **Cell will be described as "component cells" in harmonized with other industry. Such as IEC or UN regulations.**
5. **The main items will be " performance"," safety", and " logistics", but " disposal" or "recycle"**

3. Approach

3.1 Studying the existing Documents
- **Classify according lifecycle,**
- **Comparing each documents,**
- **Merging similar requirements or testing**

3.2 Harmonize and clarify each items
- **Entries with gap will be harmonized.**
- **Vague descriptions will be clarified.**

Difficult and important

Need more discussions

3.3 Contents of the document will be constructed.

Chec k

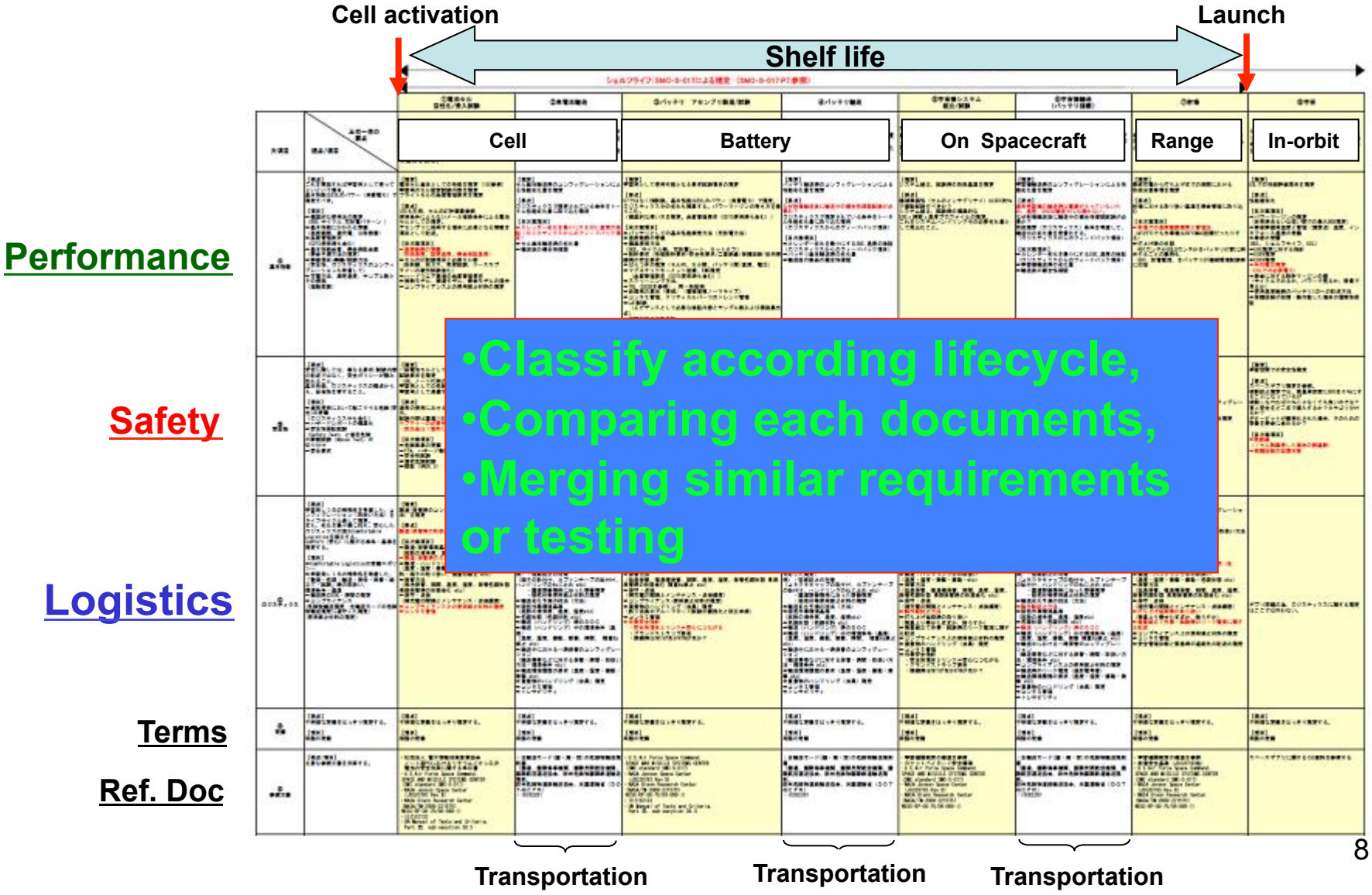
Describe each item or entry in detail

International Standard document!

3.1 Studying the existing Documents

Organization	Document	Document No.
U.S. Air Force Space Command, SPACE AND MISSILE SYSTEMS CENTER	LITHIUM-ION BATTERY FOR SPACECRAFT PPLICATIONS	SMC standard SMC-S-017 13,June,2008 (Planned for conversion to and AIAA)
U.S. Air Force Range Safety Office	Eastern and Western Range 127-1, Range Safety Requirements	EWR-127-1
NASA Jonson Space Center	CREWED SPACE VEHICLE BATTERY SAFETY REQUIREMENTS	JSC20793.Rev.B April,2006
NASA Glenn Research Center	Guidelines on Lithium-ion Battery Use in Space Applications	NASA/TM-2009-2215751NESC-RP-08-75/06-069-I May 2009
U.S. DEPARTMENT OF DEFENSE	DEPARTMENT OF DEFENSE TEST METHOD STANDARD ENVIRONMENTAL ENGINEERING CONSIDERATIONS AND LABORATORY TESTS	MIL-STD-810
JAXA	System Safety Standard	JMR-001B
	ROCKET PAYLOAD SAFETY REQUIREMENTS	JMR-002B
	Electric Design Standard	JERG-2-214
	Safety Design Guideline for General Use Battery	CSA-108024
	PACKAGING, TRANSPORTATION AND STORAGE HANDBOOK	JERG-0-038
United Nations	UN Model Regulation, Transport of Dangerous Goods Manual of Tests and Criteria (Rev.5)	Transport of Dangerous Goods UN Manual of Tests and Criteria, Part Ⅲ, sub-section 38.3
IEC	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications	IES62133
	Safety of primary and secondary lithium cells and batteries during transport	IEC62281
Underwriters Laboratories Inc (UL)	Lithium Batteries	UL1642

3.1 Studying the existing Documents



3.2. Harmonize and clarify each items (Trinity Image)

Note: Each item is in some sense individual, but always related as well ⟷

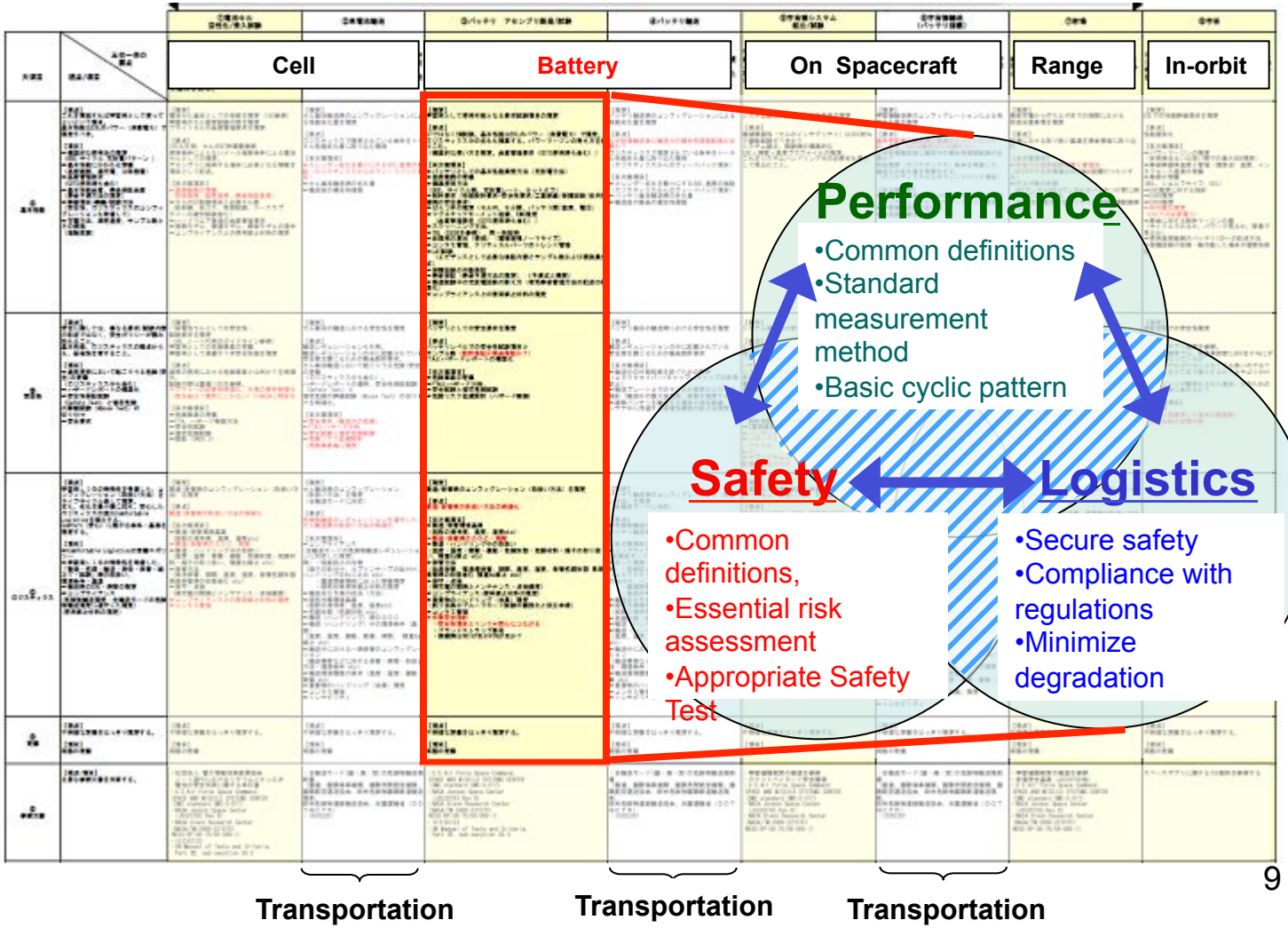
Performance

Safety

Logistics

Terms

Ref. Doc



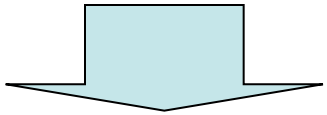
3.3 Contents of the document (See Attached “Contents list [DRAFT]”)

Examples

- Terms and definition
- Performance
  - Rated Capacity
  - How to determine full charge state
  - Environment (vibration, shock, humidity)
  - Representative Temperature during lifecycle
  - Typical charge/discharge cycle for space craft
  - How to determine Service Life
- Safety
  - Risk Analysis
  - Safety and Abuse Test items and method
  - Hazard control
- Logistics
  - Handling method
  - Conditions during handling and transportation
- Application example.

Summary and Conclusions

- Study for the international standardization of Lithium-ion battery for spacecraft has been initiated.
- The purpose is to establish the common recognition about the performance, safety and logistics in the world space industry.
- The industrial standard should be based on the considerable experience and traditional policy of space activities.



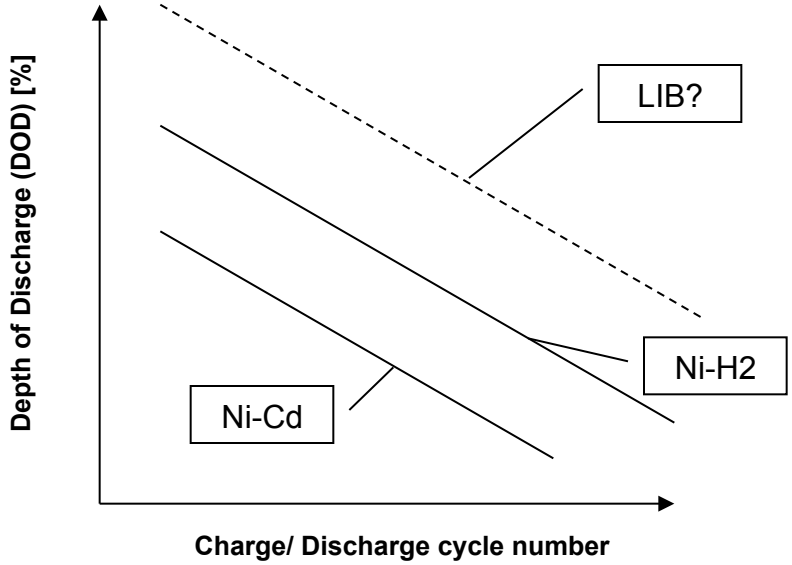
Please provide any comments through the meeting or contact directly to the each country specialist!

Appendix
Study examples of the item for standard

Examples of standard items
(1)Typical usage (Performance)

•Most interesting thing in the application of LIB is performance

•There is no guideline for LIB because no single guideline covers various chemistries, while the traditional batteries have guidelines.



Assuming typical usage of charge/discharge pattern will be able to defined, ex.DOD25%, 75%, 100% on 15 deg.C baseline temperature with manufacturer recommended end of charge voltage and cut off discharge voltage.

The cycle numbers will be achieved for the various chemistry LIB.
This could be the general guideline for the performance.

Examples of standard items
(2) Definition of Rated Capacity (Performance)

Rated capacity is the base parameter of the definitions of other performance characteristics. Although, at this moment, the definitions of rated capacity depends on manufacturer's recommendation. The rated capacity is also used to define the guaranteed capacity for the cell shipment.

Example,

➢Definition of Depth of Discharge (DOD).
(Ref;NASA/TM-2009-215751,48p, SMC-S-017, 3p)
Battery DOD（%）＝[Capacity (Ah) removed/ Capacity (Ah) rated]*100

➢Definition of State of Charge (SOC).
(Ref;NASA/TM-2009-215751,49p, SMC-S-017, 4p)
Battery SOC（%）＝[Capacity (Ah) present/ Capacity (Ah) rated]*100

DOD is a representative parameter for life estimation, and SOC is also a key parameter for life and safety.

Examples of standard items
(2) Definition of Rated Capacity (Continued)

Case study ; Sizing battery with the Maximum allowable DOD 70%

	Manufacturer A	Manufacturer B
Actual Capacity	110Ah	110Ah
Rated Capacity (Guaranteed)	100Ah	90Ah
Discharge Capacity	70Ah	63Ah
Actual DOD	63.6%←（70Ah/110Ah）	57.3%←（63Ah/110Ah）
Electrical Power Design at Apace craft	Capacity large, Deep DOD ,degradation worth	Shallow DOD, less degradation, less Capacity
Necessary cell number	Less	More

①Yield ratio worsens at cell manufacturer by narrowing the discrepancy

⇔

②Wider the discrepancy, worse in specific energy and cost competitiveness at spacecraft manufacturer

How should the Rated capacity be determined?

Examples of standard items

(3) Safety

・It is needed to clarify what safe should be ensure from battery hazard commonly throughout several chemistry technology.

(Explosion, vent , fire, smoke, voltage, corrosion …..)

・How to harmonize the safety control covered traditional space qualified battery and COTS one.

・Risk assessment or Failure Tree Analysis should be common in the world to maintain the safety quality.

・It is needed to classify the evaluation level as to accommodate mission.

(Manned, Un-manned, commercial satellite, experimental…)

・To harmonized with other regal regulation is needed (ex.UN38.3/IEC)

Examples of standard items
(4) Logistics

When transporting LIB, it is treated as a Dangerous Goods of UN Regulation.
To maximize on-orbit performance, aging degradation should be minimize before launch. Therefore , the transportation must be smoothly conducted.
Although the actual operation of logistics (transportation) does not go as smoothly as planned due to handover between the transportation carriers (hereafter referred to as third party logistics) and the shipper (battery manufacturer). There is a discrepancy of recognition concerning risks of dangerous goods (LIB) and resulting differences in handling.

Smooth transportation cannot be achieved just by complying with the regulations. Most important thing is to gain the trust of the third party logistics people that Space LIB is safe in their normal operations.
The shipper consigns the flight LIB to the third party logistics (forwarder and carrier), but the third party logistics never guarantees to comply with the shipper's requirements completely (e.g. temperature range and shock level).
The situation seems the same for electrical vehicle industry.

What should we do to ensure quality of LIB for space use handled by the third party logistics who do not guarantee to comply with our requirements?